

Phytoplankton composition within the tidal freshwater region of the James River, Virginia

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Abstract.—Based on a 10.5 year data set, 271 taxa were identified at a single tidal freshwater station in the James River. The mean monthly concentrations of major algal categories, total biomass and productivity are given. Diatom maxima were associated with peak periods of river discharge, with chlorophytes, cyanobacteria, and autotrophic picoplankton abundance and productivity greater during reduced river flow and more stable water conditions.

Within the tidal stretch of estuarine rivers, there is a unique and little studied region dominated by freshwater plankton, yet it is subjected to daily tidal influence and the occasional intrusion of estuarine species. These waters are referred to as tidal fresh. The channel divisions between freshwater, tidal fresh, and oligohaline sections of a river are not constant, but will move longitudinally within the river basin in response to changes in the amount of river flow and tidal influence. During a period of drought, the range of the tidal fresh area moves farther upstream, whereas, during the seasonal rains, it would extend farther downstream. The abundance of tidal fresh algae in this region has been associated to hydrodynamic events in the river, with cell concentrations inversely related to freshwater input and directly related to the water's residency time (Jackson et al. 1987, Schuchardt & Schirmer 1991, Jones et al. 1992). Other major environmental factors influencing abundance in this region include turbidity, nutrients, tidal cycles, and light availability (Cole et al. 1982, Cloern et al. 1983, Cloern 1987, Haas et al. 1981, Jones 1991). The extent of dominance by freshwater algae downstream varies within different estuaries, but the downstream flora

will be dominated by estuarine species (Haerte et al. 1969, Forester 1973, Jackson et al. 1987, Marshall & Alden 1990). In tidal freshwater (<0.5 ppt), the algae are mainly composed of chlorophytes, cyanobacteria, and diatoms (Forester 1973, Opute 1990, Marshall 1994), with diatoms often predominating (Haertel et al. 1969, Jackson et al. 1987, Schuchardt & Schirmer 1991). Diatoms are more common during periods of high river discharge in contrast to chlorophytes, cyanobacteria, and phytoflagellates, which are more dominant during low river discharge (Farrell 1994, Schmidt 1994).

The James River is a major tributary of the Chesapeake Bay, with a drainage basin of 26,440 km², a length of 545 km and a mean monthly discharge rate of approximately 7100 ft³ sec⁻¹ (Belval et al. 1995). Within the southern Chesapeake Bay tributaries, several studies have compared phytoplankton spatial and temporal distribution within the tidal fresh and saline sections of these rivers (Marshall & Alden 1990, Marshall & Affronti 1992, Marshall 1994). These studies indicate the transport of estuarine species upstream via sub-surface waters and the transition to estuarine species dominance downstream. Marshall and

Alden (1990) recognized two distinct and dominant assemblages within the tidal James River. These were tidal fresh and oligo-mesohaline populations. The tidal freshwater group was dominated by the centric diatoms *Skeletonema potamos*, *Cyclotella striata*, and several *Aulacoseira* spp. Estuarine diatoms became dominant downstream. These included *Skeletonema costatum*, *Leptocylindrus minimus*, and *Cyclotella caspia* (*C. choctawhatcheeana*). In the James River, Filardo and Dunstan (1985) reported productivity in the lower saline regions was inversely correlated to river discharge. They noted inverse relationships between phytoplankton abundance in the oligohaline reach of the river to phytoplankton biomass downstream, suggesting this region may control nutrient availability downstream. Other studies within Chesapeake Bay tributaries have indicated phytoplankton development may become nutrient limited in spring due to reduced phosphorus and silicon levels, and in late summer as nitrogen levels decrease (Anderson 1986, Webb 1988). Based on a 5-year study of the James River, Belval et al. (1995) reported median annual concentrations near the fall line of total nitrogen (TN) and total phosphorus (TP) as 0.74 and 0.15 mg l⁻¹, respectively. The median value for dissolved orthophosphate was 0.04 mg l⁻¹. They found total nitrogen, total phosphorus, and total suspended solids (TSS) directly related to increase river discharge, and dissolved orthophosphate increased with periods of reduced river flow (and summer). Mean annual productivity for the tidal freshwater station (TF5.5) in the James River was reported by Marshall & Nesius (1993) as 279.9 gC m² yr⁻¹, with higher values noted downstream. Using a 5-year data set for the station in this study (TF5.5), they gave mean water concentrations for the following parameters (in mg l⁻¹: Si (5.8), O₂ (8.5), TP (0.16), TN (0.89), and TSS (30.3), and a mean pH of 7.5. In the tidal freshwater section of the Potomac River, Jones (1991) associated high photosyn-

thesis rates during cyanobacteria blooms to increased pH (>9) and the release of sediment phosphorus into the water column, which may then stimulate more productivity.

The objectives of this study are to: 1) identify phytoplankton taxa at a tidal freshwater station in the James River, and 2) present the mean monthly concentration levels for the dominant phytoplankton categories in this region. This information will come from a 10.5-year data base at this station.

Methods

Phytoplankton composition and abundance were determined from a vertical series from surface to bottom of monthly composite water samples taken from July 1986 through December 1996 at Station TF5.5 in the James River as part of the Chesapeake Bay Plankton Monitoring Program (Marshall & Alden 1990). The station is located above the turbidity maximum zone (37°18'46"N, 77°13'59"W), with mean water depth of 10.6 m, and a tidal range of <1 m (Marshall 1994). Monthly 500 ml sub-samples were taken for analysis using a modified Utermöhl method to settle, siphon, and concentrate the water sample into settling chambers for microscope analysis (Marshall & Alden 1990). Identification and cell abundance for each sample were based on a minimum microscope count of 200 cells, using a minimum of 10 random fields examined at both 315× and 500×, in addition to having the entire bottom of the settling chamber scanned at 125× for larger, less abundant cells that may be missed in the random field counts. The autotrophic picoplankton component and productivity values are based on a 7.5 year data set derived from monthly samples taken from July 1989 through December 1996. The autotrophic picoplankton were distinguished from heterotrophic cells using epifluorescence microscopy (Marshall 1995), with ¹⁴C productivity measurements taken

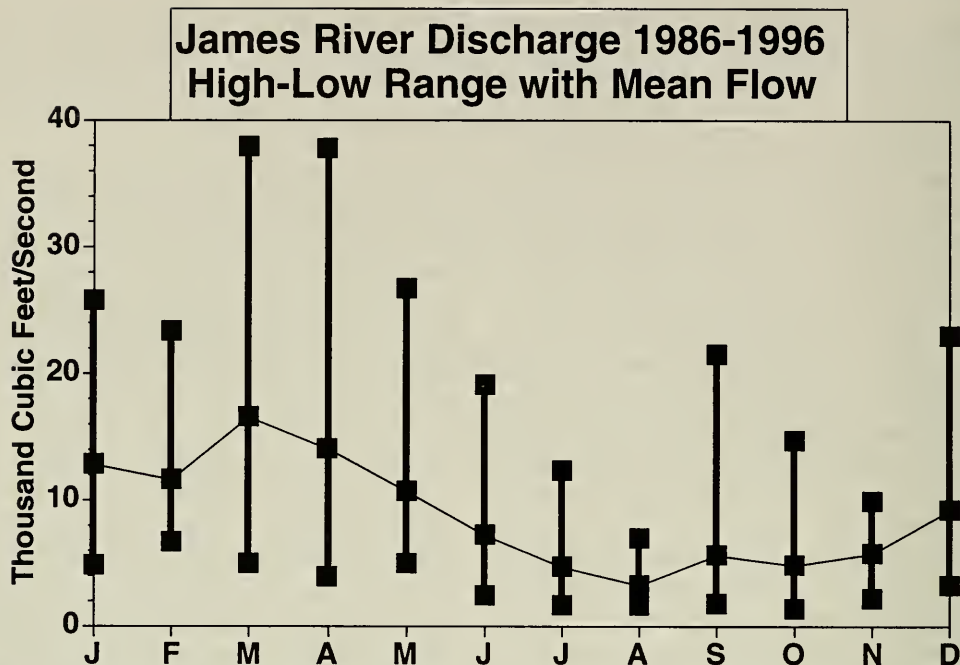


Fig. 1. High-low and mean monthly river discharge rates in the James River (fall line values), 1986 through 1996.

as described by Marshall and Nesius (1993). A 12-month set of samples from 1995 were also re-examined for further species identification using both light and scanning electron microscopy. Biomass was calculated from cell volume measurements as cell carbon (Smayda 1978). Reference to seasons uses December, January and February as winter, followed by the sequential 3-month periods for spring, summer, and fall. Water discharge rates were provided through the information data bank of the U.S. Geological Survey.

Results

The tidal fresh station (TF5.5) maintained <0.5 ppt salinity during this study. A total of 271 taxa were identified within the following categories: Bacillariophyceae (78), Chlorophyceae (94), cyanobacteria (36), Xanthophyceae (19), Euglenophyceae (15), Dinophyceae (13), Chrysophyceae (9), and Cryptophyceae (7). The autotrophic picoplankton were collectively com-

posed as a composite group, but consisted mainly of single-celled cyanobacteria, but these are not included in the cyanobacteria concentrations given in Fig. 4.

The pattern of river discharge in the James river is maximum flow in spring, reduced discharge during summer, and an increase during fall and winter (Fig. 1). The greatest monthly ranges for flow occurred during the period of spring rains in March and April, and least during summer. During the 10.5-year study, annual mean monthly flows ranged from 4495 (1988) to 13,192 (1996) $\text{ft}^3 \text{sec}^{-1}$. Many of the high monthly ranges represented extreme, and not common occurrences; therefore the mean flow rate is considered here more typical for each month. The most consistent and least variable months of flow were July and August. During these months the salinity gradients would move farther upstream and more stratified water column conditions would exist in the river, in contrast to the high discharge periods of spring. Consid-

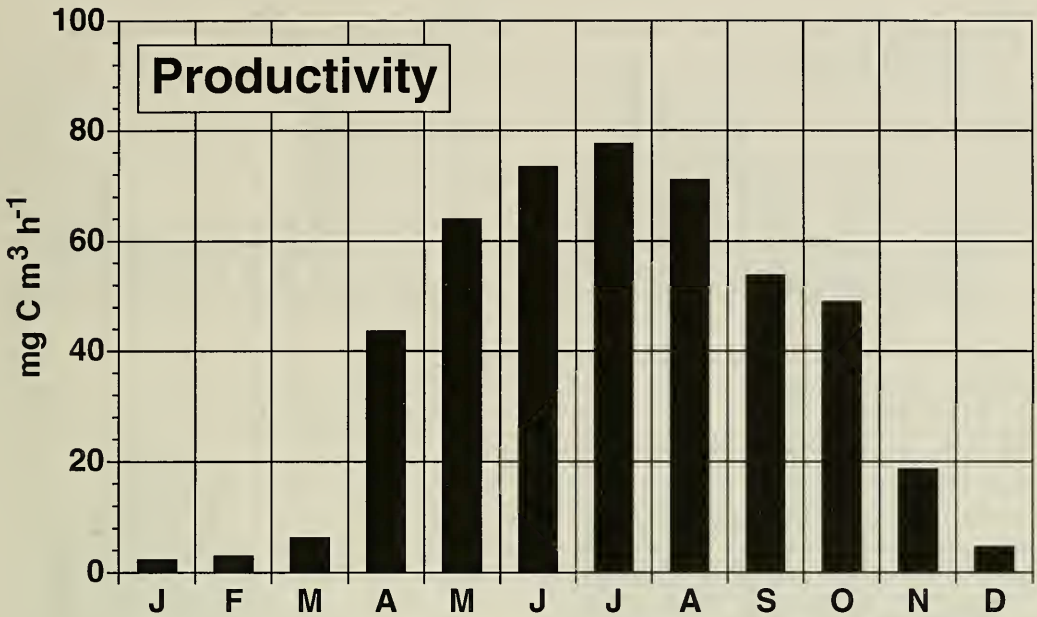


Fig. 2. Mean monthly productivity rates at the tidal freshwater station (TF5.5) from July 1989 through December 1996.

erable variability in the amount and timing of river discharge occurred, which influenced the residency time and period of development for phytoplankton in the water column.

The mean monthly productivity for this site is given in Fig. 2. The period of highest productivity occurred between mid-spring (April) and continued into mid-fall (October). These values decreased into winter. The lowest production levels were in January at $2.3 \text{ mgC m}^3 \text{ hr}^{-1}$ (Fig. 2). In summer, they reached $71\text{--}77 \text{ mgC m}^3 \text{ hr}^{-1}$. This period coincided with maximum development of the total phytoplankton and autotrophic picoplankton components. The spring and fall pulses were dominated by diatoms, whereas the summer months contained a diverse assemblage of phytoplankton that contributed to this productivity.

The phytoplankton composition was dominated by freshwater diatoms, chlorophytes, cyanobacteria, and cryptomonads. Maximum total phytoplankton abundance occurred during April ($64 \times 10^6 \text{ cells l}^{-1}$) and from July through October ($79\text{--}109 \times$

$10^6 \text{ cells l}^{-1}$), after which came a sharp decrease into winter (Figs. 3, 4). The spring development was a product of the diatom pulse, whereas a combination of chlorophytes, diatoms, and cyanobacteria were mainly responsible for the summer and fall growth. The mean monthly biomass pattern was similar to phytoplankton concentrations, having greater biomass occurring in spring and from mid-summer through fall (Fig. 3). In addition to the primary categories responsible for the cellular abundance mentioned above, the biomass levels were enhanced by euglenophytes during their peak time of development in July and August (Fig. 4).

Bacillariophyceae.—The lowest diatom concentrations ($3 \times 10^6 \text{ cells l}^{-1}$) were in winter and early spring (Fig. 3). Cell numbers increased with peak abundance occurring during the spring pulse (April and May), when mean concentrations reached $41 \times 10^6 \text{ cells l}^{-1}$. The maximum diatom development also coincided with the peak discharge period of April. There were reduced diatom concentrations in summer,

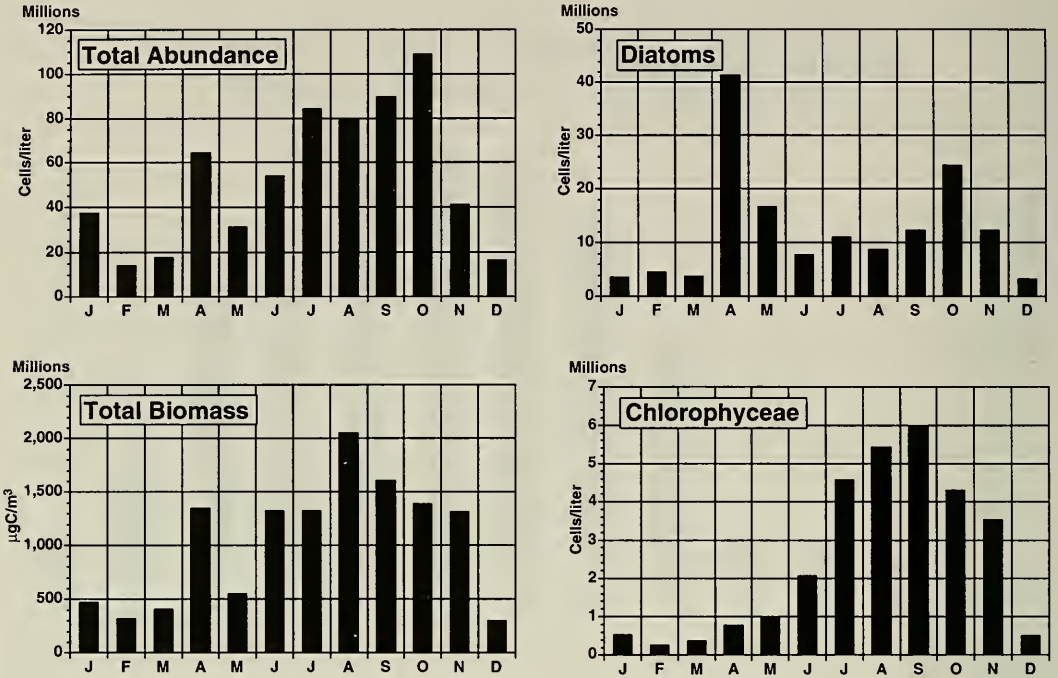


Fig. 3. Mean monthly abundance for total phytoplankton, diatoms, and chlorophytes, and the mean monthly phytoplankton biomass at the tidal freshwater station, (TF5.5), July 1986–December 1996.

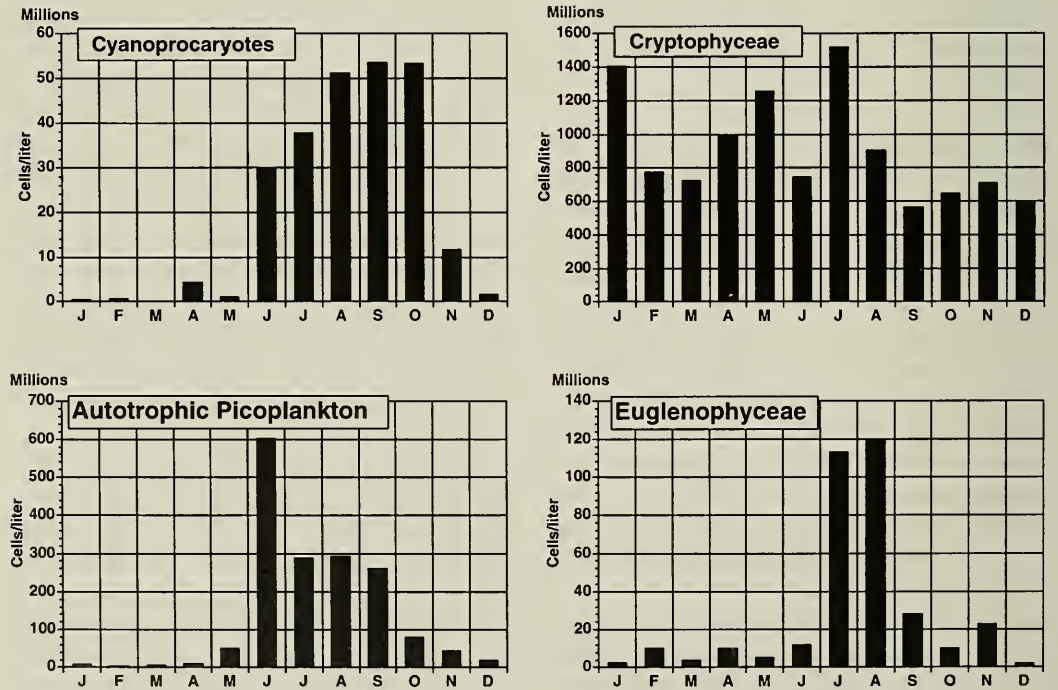


Fig. 4. Mean monthly abundance at the tidal freshwater station (TF5.5) for cyanobacteria, cryptophytes, and euglenoids from July 1986–December 1996, and for the autotrophic picoplankton July 1989–December 1996.

during a time of reduced river flow, which was then followed by a less developed fall pulse ($20\text{--}25 \times 10^6$ cells l^{-1}) in October. The species most responsible for the spring and fall maxima were freshwater centric diatoms: *Actinocyclus normanii*, *Aulacoseira granulata*, *A. granulata* v. *angustissima*, *Cyclotella striata*, *C. meneghiniana*, *Cyclostephanos* spp., *Melosira varians*, *Skeletonema potamos*, *Stephanodiscus hantzschii*, and *Thalassiosira lacustris*. Of these, *Skeletonema potamos* was most abundant during seasonal maxima and present throughout the year. In addition, the abundant pennate diatoms included *Cymbella affinis*, *Nitzschia acicularis*, several other *Nitzschia* spp., *Staurosirella leptostauron*, and *Surirella elegans*. Many of these centric and pennate species have also been recorded downstream in the James River, but decreasing in their abundance with increased salinity (Marshall 1994). The majority of the estuarine diatoms recorded for this site were noted in <2% of the samples. More frequently recorded (13–19% of the collections) were *Skeletonema costatum*, *Leptocylindrus danicus*, and *L. minimus*.

Chlorophyceae.—The chlorophytes had the largest number of taxa (94) among the algae, with their greatest abundance in summer and fall (Fig. 3). Development coincided with the decrease of the spring diatom bloom, reduced river flow, and accompanied the increase of cyanobacteria. Highest numbers were recorded during this period ($4\text{--}5 \times 10^6$ cells l^{-1}), with reduced concentrations during winter and spring. The most widely represented genera included: *Ankistrodesmus*, *Crucigenia*, *Kirchneriella*, *Monoraphidium*, *Scenedesmus*, *Staurastrum*, *Tetraedron*, and *Tetrastrum*. None of the chlorophytes dominated the phytoplankton in abundance; however, they were common constituents of the algal community throughout the year.

Cyanobacteria.—This category was represented by a variety of filamentous and colonial species that were most abundant (Fig. 4) from early summer (June) to mid-fall

(October). Their peak development was at 50×10^6 cells l^{-1} (August–October). Cell abundance then declined rapidly into winter and remained low through spring. The most common species throughout the year were *Chroococcus minor*, *Dactylococcopsis acicularis*, *D. raphidioides*, *Merismopedia punctata*, *Oscillatoria agardhii*, and *O. limnetica*. These taxa were major contributors to the summer–fall maximum. Other species in abundance included *Anabaena solitaria*, *A. affinis*, *Gomphosphaeria lacustris*, *Merismopedia tenuissima*, and *M. glauca*. This group was associated with a more stratified water column, increased water temperatures, and reduced river discharge.

Cryptophyceae.—The cryptomonads represented a ubiquitous and abundant component of the phytoplankton assemblages throughout the year, and are also common in the downstream tidal sectors of the James River (Marshall & Alden 1990). Their mean monthly concentrations for the year ranged from $5\text{--}15 \times 10^5$ cells l^{-1} (Fig. 4). They were most abundant in winter (Dec.), late spring (May), and mid-summer (July). *Cryptomonas marssoni* was present during each season. Other widely distributed species were *Cryptomonas ovata* and *Rhodomonas minuta*. The peak abundance of cryptomonads was associated with reduced river discharge and summer.

Autotrophic picoplankton.—The autotrophic picoplankton consisted of mainly single cell cyanobacteria $0.5\text{--}1.5 \mu\text{m}$ in size (e.g. *Synechococcus* sp.) and represent a ubiquitous component of the James River and Chesapeake Bay (Marshall & Nesius 1993, Marshall 1995). Their peak abundance was during the summer months at $26\text{--}60 \times 10^7$ cells l^{-1} (Fig. 4). Their lowest concentrations occurred in February and March ($3\text{--}5 \times 10^6$ cells l^{-1}). Some chlorophytes were also present in this group, but they represented only a small fraction of the composition. A major importance of the autotrophic picoplankton in the James River and the lower Chesapeake Bay is

their contribution to the total summer productivity (Marshall & Nesius 1993).

Other categories.—The euglenophytes were generally found in low concentrations throughout the year, with the exception of July and August, when their mean concentrations reached 11×10^5 cells l^{-1} (Fig. 4). Common taxa included *Euglena viridis* and *E. oxyuris*, with other *Euglena*, *Phacus*, *Trachelomonas*, and *Strombomonas* species less abundant. The xanthophytes were recorded throughout the year. However, they were generally noted in low concentrations, with low monthly species diversity. *Tribonema monochloris* was the most common species. Several species were associated with increased summer and fall development. These included *Dichromococcus curvatus* and *Pseudotetraedron neglectum*, whereas *Botrydiopsis eriensis* and *B. arhiza* were noted in spring and summer. Other species within this category were less common.

The chrysophytes were represented by 5 *Dinobryon* species, *Synura uvella*, *Lagynion cystodini*, and *Dictyota fibula*. *Dinobryon sociale* was most frequently noted in late winter and early spring. *Dictyota fibula* was rare (1% of the samples), coming from an infrequent intrusion of downstream water into this region. The dinoflagellate populations were also low, with their counts enhanced by occasional sporadic growth periods. The maximum development of dinoflagellates occurred in winter (January) and between late spring (June) and fall (August), with mean concentrations of $2-6 \times 10^4$ cells l^{-1} during summer months. There was low species diversity of dinoflagellates throughout the year, with a limited number of dominant taxa. The genera most frequently identified were *Gymnodinium*, *Gyrodinium*, *Peridinium*, and *Prorocentrum*. Downstream species that occurred within these collections included *Heterocapsa triquetra*, *Prorocentrum micans*, and *P. minimum*. The more common freshwater species were *Ceratium hirundinella* and *Peridinium williei*.

Summary

The tidal fresh region of the James River contained a diverse and abundant phytoplankton flora. A total of 271 taxa were identified, with the most abundant species chlorophytes (94), diatoms (78), and cyanobacteria (36). The region was dominated by freshwater algae, but there were also some estuarine diatoms and phytoflagellates recorded for the site. The recording of estuarine taxa was probably enhanced by the extensive sampling base, which provided more opportunities for these species to be recorded for this region, e.g., during storm events and periods of low river discharge, etc., over 10.5 years. However, the majority of these species occurred in <2% of the collections. A high degree of representation by estuarine species in this region would not be expected to occur during each monthly collection.

There was monthly and annual variability in river discharge at this station. Although the use of mean discharge rates and mean phytoplankton concentrations presented here do not identify close annual relationships, a pattern is present. Peak development of diatoms (the spring pulse) occurred during periods of increased river discharge, while the high populations of chlorophytes, cyanobacteria, autotrophic picoplankton, and euglenophytes were closely associated to periods of reduced flow and more stable water conditions. These findings support results presented by Farrell (1994), Schmidt (1994), and others.

Peak periods of phytoplankton abundance extended from spring through fall, with different algal categories showing a successional pattern of development. Winter was the period of least abundance, biomass, and productivity, with low concentrations of diatoms, chlorophytes, and cryptomonads as the common constituents. The spring bloom of freshwater diatoms, mainly by *Skeletonema potamos*, was followed by increased concentrations of chlorophytes into early summer. The summer flora con-

tained high concentrations of chlorophytes, cyanobacteria, autotrophic picoplankton, euglenoids, and diatoms. This was the period for maximum values in phytoplankton and picoplankton abundance, biomass, and productivity. Into fall, the dominance of the summer constituents declined, except for the diatoms, which produced another pulse. This was followed by reduced concentrations of total phytoplankton and the autotrophic picoplankton into winter. Common background taxa to these major components included cryptophytes, euglenophytes, xanthophytes, and chrysophytes.

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Appendix 1

Phytoplankton within the tidal fresh region of the James River.

BACILLARIOPHYCEAE

- Achnanthes* sp.
Actinocyclus normanii (Gregory) Hustedt
Asterionella formosa Hassall
Asterionella glacialis Castracane
Asterionella gracillima (Hantzsch) Heiberg
Aulacoseira distans (Ehrenberg) Simonsen
Aulacoseira distans v. *humilis* (A. Cleve) R. Ross
Aulacoseira granulata (Ehrenberg) Simonsen
Aulacoseira granulata v. *angustissima* (O. Müller) Simonsen
Aulacoseira herzogii (Lemmermann) Simonsen
Aulacoseira islandica (O. Müller) Simonsen
Bacillaria paxillifer (Müller) Hendy
Chaetoceros sp.
Cocconeis sp.
Coscinodiscus marginatus Ehrenberg
Coscinodiscus sp.
Cyclostephanos sp.
Cyclostephanos dubius (Fricke in A. Schmidt) F. E. Round
Cyclotella bodanica Grunow
Cyclotella caspia Grunow
Cyclotella chaetoceros Lemmermann
Cyclotella choctawhatcheeana Prasad
Cyclotella comta (Ehrenberg) Kützing
Cyclotella meneghiniana Kützing
Cyclotella sp.
Cyclotella striata (Kützing) Grunow
Cylindrotheca closterium (Ehrenberg) Reiman & Lewin
Cymbella affinis Kützing
Cymbella sp.
Diatoma sp.
Diploneis sp.
Ditylum brightwellii (T. West) Grunow
Fragilaria capucina Desmazières
Fragilaria construens (Ehrenberg) Grunow
Fragilaria crotonensis Kitton
Fragilaria sp.
Gyrosigma fasciola (Ehrenberg) Griffith & Henfrey

- Gyrosigma littorale* (W. Smith) Griffith & Henfrey
Gyrosigma sp.
Hantzchia sp.
Leptocylindrus danicus Cleve
Leptocylindrus minimus Gran
Licmorpha sp.
Melosira moniliformis (O. F. Müller) C. Agardh
Melosira varians C. Agardh
Meridion circulare (Greville) C. Agardh
Navicula radiosa Kützing
Navicula sp.
Nitzschia acicularis (Kützing) W. Smith
Nitzschia obtusa W. Smith
Nitzschia sigma (Kützing) W. Smith
Nitzschia sp.
Pinnularia sp.
Pleurosigma angulatum (Quekett) W. Smith
Pleurosigma elongatum W. Smith
Pleurosigma sp.
Pseudonitzschia pungens Grunow
Rhaphoneis amphiceros (Ehrenberg) Ehrenberg
Rhaphoneis surirella (Ehrenberg) Grunow
Rhizosolenia delicatula Cleve
Skeletonema costatum (Greville) Cleve
Skeletonema potamos (Weber) Hasle
Stauroneis sp.
Staurosirella leptostauron (Ehrenberg) Williams & Round
Stephanodiscus hantzschii Grunow
Stephanodiscus sp.
Surirella elegans Kützing
Surirella ovata Kützing
Surirella robusta Ehrenberg
Surirella sp.
Surirella tenera Gregory
Synedra acus Kützing
Synedra sp.
Synedra ulna (Nitzsch) Ehrenberg
Tabellaria sp.
Thalassionema nitzschioides (Grunow) Grunow
Thalassiosira lacustris (Grunow) Hasle & Fryxell
Tryblionella punctata W. Smith
- CHLOROPHYCEAE
- Acenedesmus acuminatus* (Lagerheim) Chodat
Actinastrum hantzschii Lagerheim
Actinastrum hantzschii v. *fluviatile* Schröder
Ankistrodesmus gracilis (Reinsch) Korschikov
Ankistrodesmus falcatus (Corda) Ralfs
Ankistrodesmus falcatus v. *acicularis* (A. Braun) G. S. Smith
Ankistrodesmus longissimus (Lemmermann) Wille
Carteria fornicata Nygaard
Carteria sp.
Chlamydomonas sp.
Chlamydomonas pertyi Goroshankin
Chlorella vulgaris Beyer
Closteropsis acicularis (G. M. Smith) Belcher & Swale

- Closteriopsis longissima* (Lemmermann) Lemmermann
Closterium acutum Lyngbye ex Ralfs
Closterium sp.
Coelastrum microporum Nägeli
Cosmarium rectangulare Grunow
Cosmarium sp.
Crucigenia apiculata (Lemmermann) Schmidle
Crucigenia crucifera (Wolle) Collins
Crucigenia fenestrata (Schmidle) Schmidle
Crucigenia tetrapedia (Kirchner) W. ex G.S. West
Crucigenia quadrata Morner
Crucigenia rectangularis (A. Braun) Gay
Crucigenia sp.
Dictyosphaerium ehrenbergianum Nägeli
Dictyosphaerium tetrachotomium Printz
Didymocystis planctonica Korschikov
Diplocloris hoefleri (Bour) Hindák
Endorina cylindrica Korschikov
Euastrum gayanum DeToni
Franceia elongata Korschikov
Hyaloraphidium arcuatum Korschikov
Hyaloraphidium contortum Pascher & Korschikov
Kirchneriella contorta (Schmidle) Bohlin
Kirchneriella lunaris (Kirchner) Moebius
Kirchneriella irregularis v. *spiralis* (Smith) Korschikov
Kirchneriella obesa (W. West) Schmidle
Kirchneriella sp.
Koliella longiseta (Vischer) Hindák
Micractinium pusillum Fresenius
Monoraphidium arcuatum (Korschikov) Hindák
Monoraphidium contortum (Thuret) Komárková-Legnerová
Monoraphidium griffithii (Berkel) Komárková-Legnerová
Monoraphidium minutum (Nägeli) Komárková-Legnerová
Monoraphidium obtusum (Korschikov) Komárková-Legnerová
Monoraphidium pusillum (Printz) Komárková-Legnerová
Oocystis coronata Lemmermann
Oocystis solitaria Wittrock
Pediastrum biradiatum Meyen
Pediastrum boryanum v. *longicornum* Reinsch
Pediastrum duplex Meyen
Pediastrum duplex v. *inflata* Wolosz
Pediastrum simplex (Meyen) Lemmermann
Pediastrum tetras (Ehrenberg) Ralfs
Phacotus sp.
Phacotus lenticularis Ehrenberg
Quadrigula lacustris (Chodat) G. M. Smith
Quadrigula phitzeri (Schröder) G. M. Smith
Scenedesmus acuminatus (Lagerheim) Chodat
Scenedesmus armatus Chodat
Scenedesmus bicaudatus (Hansgirg) Chodat
Scenedesmus bijuga (Turpin) Lagerheim
Scenedesmus bijuga v. *alternans* (Reinsch) Hansgirg
Scenedesmus denticulatus Lagerheim
Scenedesmus dimorphus (Turpin) Kützing
Scenedesmus disciformis (Chodat) Fott & Komárková
Scenedesmus ecornis (Ralfs) Chodat
Scenedesmus magnus Meyen
Scenedesmus obliquus (Turpin) Kützing
Scenedesmus opoliensis Richter
Scenedesmus quadricauda (Turpin) Brébisson
Scenedesmus smithii Lemmermann
Scenedesmus sp.
Schroederia setigera (Schröder) Lemmermann
Staurastrum americanum (West) G. M. Smith
Staurastrum chaetoceras (Schröder) G. S. Smith
Staurastrum paradoxum Meyen
Staurastrum sp.
Staurastrum tetracerum Ralfs
Tetraëdron arthrodesmiforme (W. West) Woloszynska
Tetraëdron gracile (Reinsch) Hansgirg
Tetraëdron minimum (A. Braun) Hansgirg
Tetraëdron regulare Kützing
Tetraëdron sp.
Tetraëdron triacanthum Korschikov
Tetraëdron trigonium (Nägeli) Hansgirg
Tetrastrum elegans Playfair
Tetrastrum heteracanthum (Nordstedt) Chodat
Tetrastrum staurogeniaeforme (Schröder) Lemmermann
Treubaria setigera (Archer) D. M. Smith
Westella botryoides (W. West) de Wildermann
Xanthidium antilopeum Ehrenberg ex Kützing
- CYANOBACTERIA**
- Anabaena affinis* Lemmermann
Anabaena flos-aquae Brébisson
Anabaena reniformis Lemmermann emend. Aptekay
Anabaena sp.
Anabaena spiroides Klebahn
Anabaena solitaria Klebs
Aphanizomenon flos-aquae (L.) Ralfs
Aphanizomenon issatschenkoi (Ussac.) Proschkina-Lavenko
Chroococcus limneticus Lemmermann
Chroococcus minor (Kützing) Nägeli
Dactylococcopsis acicularis Lemmermann
Dactylococcopsis raphidioides Hansgirg
Gomphosphaeria aponina Kützing
Gomphosphaeria fusca Skuja
Gomphosphaeria lacustris Chodat
Gomphosphaeria naegelianae (Unger) Lemmermann
Lyngbya contorta Lemmermann
Merismopedia elegans A. Braun
Merismopedia glauca (Ehrenberg) Nägeli
Merismopedia punctata Meyen
Merismopedia tenuissima Lemmermann
Microcystis aeruginosa Kützing
Microcystis firma (Brébisson & Lemmermann) Schmidle
Microcystis incerta Lemmermann

Microcystis viridis (A. Braun) Lemmermann
Microcystis wesenbergii Komárková
Nostoc commune Vaucher
Nostoc sp.
Oscillatoria agardhii Gomont
Oscillatoria limnetica Lemmermann
Oscillatoria sp.
Phormidium sp.
Spirulina major Kützing
Spirulina sp.
Spirulina subsalsa Oersted
Synechococcus sp.

XANTHOPHYCEAE

Botrydiopsis arhiza Borzi
Botrydiopsis eriensis Snow
Centritractus brunneus Fott
Centritractus capilifer Pascher
Centritractus globulosus Pascher
Characiopsis subulata (A. Braun) Borzi
Dichotomococcus curvatus Korschikov
Gleobotrys limneticus (G. M. Smith) Pascher
Goniochloris pulcherrima Pascher
Isthmochloron lobulatum (Nägeli.) Skuja
Pseudotetraedron neglectum Pascher
Tetraedriella spinigera Skuja
Tribonema aequale Pascher
Tribonema affine G. S. West
Tribonema ambiguum Skuja
Tribonema monochloron Pascher & Geitler
Tribonema pyrenigerum Pascher
Tribonema subtilissimum Pascher
Tribonema vulgare Pascher

EUGLENOPHYCEAE

Euglena acus Ehrenberg
Euglena ehrenbergii Klebs
Euglena gracilis Klebs
Euglena oblonga Schmitz
Euglena oxyuris Schmarda
Euglena tripteris (Dujardin) Klebs
Euglena viridis Ehrenberg

Phacus lemmermannii (Swirenko) Skvortzow
Phacus longicauda (Ehrenberg) Dujardin
Phacus suecicus Lemmermann
Phacus sp.

Strombomonas borysteniensis (Roll) Popova
Strombomonas sp.
Trachelomonas hispida (Perty) Stein
Trachelomonas sp.

CRYPTOPHYCEAE

Cryptomonas erosa Ehrenberg
Cryptomonas curvata Ehrenberg emend. Penard
Cryptomonas marssoni Skuja
Cryptomonas ovata Ehrenberg
Cryptomonas ovata v. *curvata* (Ehrenberg) Lemmermann
Rhodomonas minuta Skuja
Rhodomonas ovata Ehrenberg

CHRYSOPHYCEAE

Dictyota fibula Ehrenberg
Dinobryon bavaricum Imhof
Dinobryon cylindricum Imhof
Dinobryon petiolatum Willen
Dinobryon sertularia Ehrenberg
Dinobryon sociale Ehrenberg
Lagnion cystodini Pascher
Synura sp.
Synura uvella Ehrenberg

DINOPHYCEAE

Ceratium hirundinella (O. F. Müller) Dujardin
Ceratium sp.
Cochlodinium sp.
Gymnodinium sp.
Gyrodinium fusiforme Kofoid & Swezy
Gyrodinium sp.
Heterocapsa triquetra (Ehrenberg) Stein
Katodinium rotundatum (Lohmann) Loeblich III
Peridinium sp.
Peridinium willei Huitfeldts-Kaas
Prorocentrum micans Ehrenberg
Prorocentrum minimum (Pavillard) Schiller
Proto-peridinium sp.